

A Compact 50 MHz High Power Solid State Amplifier using the MRFE6VP61K25H

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This article deals with an RF amplifier design using high power RF solid state devices. If you have no experience working with these high power levels, please enlist the help someone who has the necessary experience.

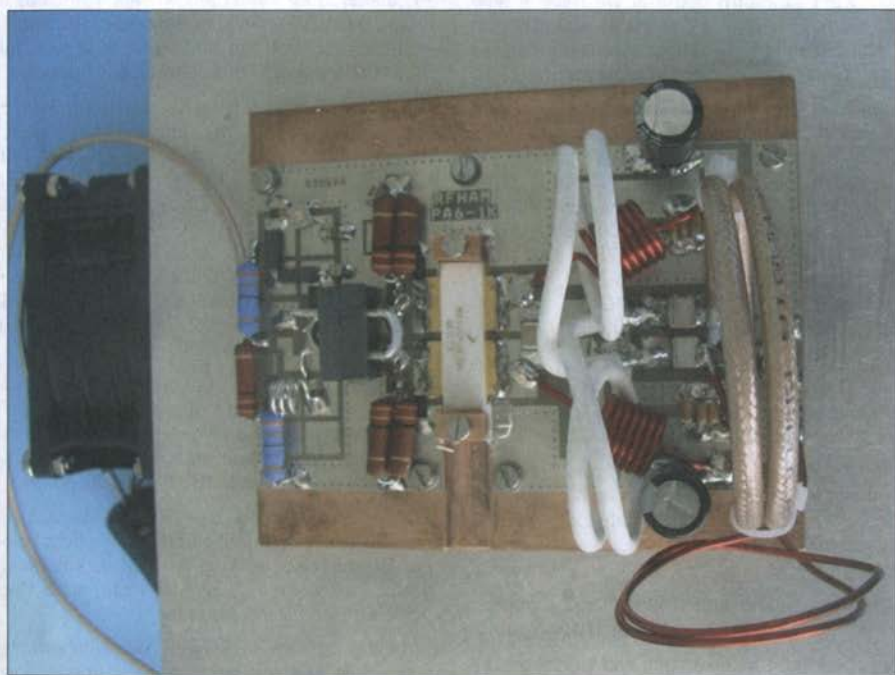


Fig. 1: 1.2 KW PA for 50MHz with new transistor

1. Introduction

Based on the article by Lionel F1JRD (AE7KX), we decided to build a 6m module. The MRFE6VP61K25H is a versatile device, well suited to a wide range of applications. It is capable of delivering 1.25KW of continuous wave output thanks to its high efficiency and low thermal resistance. It can also handle high VSWR conditions. This description focuses on the 50 MHz amateur band for both analog and digital waveforms (SSB or WSJT/FSK/CW).

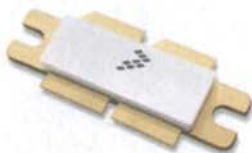


Fig. 2: MRFE6VP61K25H a 1.25KW transistor

Main characteristics are:

Frequency band: 50 - 52 MHz
Output Power @ P4dB: > 1200W
Operating supply voltage: 50V
Gain: typ > 26 dB
Efficiency: typ. > 76%
PCB Size: 12cm x 7.3cm

The MRFE6VP61K25H is part of the 50 V product line, which is designed specifically for high voltage application by Freescale for the RF power market, fabricated using Freescales proprietary Very High Voltage 6th generation with enhanced ruggedness (VHV6E) platform. This technology is fully qualified and ships in volume.

2. Advantages of 50V Drain Voltage

Using a 50V device is a great advantage compared to lower voltages because the output impedance of the device is much greater for the same output power, so the output match circuitry is simpler and less lossy. The current will also be less than at lower voltages.

In addition, 50V LDMOS provides increased power density, which enables in excess of 1.25kW in the industry standard NI1230 package platform.

50V LDMOS technology has also better IMD performance compared to lower voltage, especially bipolar technology 12V devices.

The reference fixture was designed with the market standard drain supply, allowing the amplifier to utilize a standard 50V power supply (most are adjustable 43 to 54 V).

For all technology aspects refer to DUBUS magazine issue 4/2010, vol. 39 "A Compact 144 MHz High Power Solid State Amplifier using the MRFE6VP61K25H" from F1JRD (AE7KX).

3. Amplifier design and performance

The goal of this module was to get 1 kW solid state, with good efficiency, small size and good VSWR tolerance. We based our design on the application note from Freescale MRFE6VP61K25HR6 FM broadcast (88 to 108 MHz). For all thermal aspects please refer to (1).

The PCB is made of TC350 material that has very good RF and thermal performance. The size of the amplifier board is 120 x 72 mm. The transistor has to dissipate more than 300 W in a small area, so a copper plate is necessary to transfer the heat to the aluminum heat sink. Two techniques can be used to put the PCB on the copper heat spreader: With screws like in the picture or with solder. The latter technique needs some skill and some solder paste (3).

Circuit description (see fig. 4 for circuit diagram): The transistor gain at low frequencies is very high. Thus we have to add attenuation to limit the gain. The input circuit is constructed with a 9:1 transformer like the 2m amplifier, because of the lower frequency a ferrite "E" and "I" core have been added.

The input is matched with coils L1, L2 and L3. The 500 Ohm trimmer can be removed, if an external bias circuit is used. R5, R6, R7 and R8 are used to stabilize the input circuit. C4 and C5 are for DC blocking. The 1k resistors R9 and R10 are connected to ground to prevent the bias line floating if P1 is not used. The output circuit also uses a 9:1 transformer. Particular attention should be paid to making the 10 ohm coaxial cables Coax 1 and Coax 2, see the construction details later.

C6, C7 and C8 are high Q factor capacitors of the CLX series from TEMEX. C6 (75 pF) is a part of the matching network, C7 and C8 are for DC blocking. These capacitors have a very low ESR and can handle more than 20A RF current at 300V (C7 and C8). The symmetrical output balun is made from 50 ohm Teflon coaxial cable RG142 and the same length of 1.6mm wire. This balun improves the 2nd harmonic.

RoHS

MRFE6VP61K25HR6
MRFE6VP61K25HSR6

1.8-600 MHz, 1250 W CW, 50 V
LATERAL N-CHANNEL
BROADBAND
RF POWER MOSFETS

CASE 375D-05, STYLE 1
NI-1230
MRFE6VP61K25HR6

CASE 375E-04, STYLE 1
NI-1230S
MRFE6VP61K25HSR6

PARTS ARE PUSH-PULL

Fig. 3: Datasheet extract

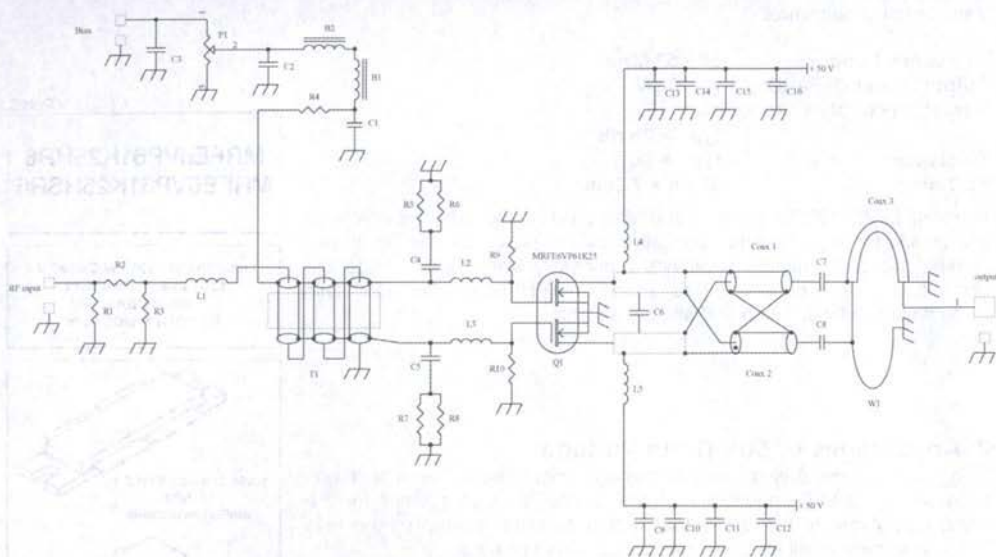


Fig. 4: Circuit diagram

4. RF measurements

The RF measurements were made using CW and without the 3 dB input attenuator.

50 V Drain supply, 2000 mA I_{dq} (for linear operation):

This test was made with the amplifier module only (without filter).

Freq (MHz)	Pin (W)	Pout (W)	Gain (dB)	IRL (dB)	Eff (%)	Vd (V)	Id (A)
50	0.1	100	30	-13	23.1	49.8	8.7
50	0.2	200	30	-13	33.5	49.8	12
50	0.3	300	30	-16	41	49.8	14.7
50	0.38	400	30.2	-17	47	49.8	17.1
50	0.51	500	29.9	-16	52.3	49.8	19.2
50	0.73	600	29.1	-16	56.3	49.8	21.4
50	0.88	700	29.0	-16	60.3	49.8	23.3
50 P1 dB	1	800	29.0	-16	64.3	49.8	25
50	1.4	900	28.1	-16	66.9	49.8	27
50	2	1000	27	-16	70	49.8	28.7
50 P6dB	4.6	1100	23.8	-17	72.4	49.8	30.5

Table 1

The harmonic test shows the 2nd @ -40 dBc and the 3rd @ -10 dBc. This means about 100 W on 150 MHz! A filter is absolutely necessary to get the harmonics below -60 dBc. We made tests with a filter described by F1TE, based a design from K8CU some years ago (3), see fig. 5.

The results with the amplifier + 91 cm RG142 + filter are shown in table 2 below (still without the input attenuator).



Fig. 5: Low Pass Filter by F1TE

50 V Drain supply, 2000 mA Idq (for linear operation):

This test was done with the amplifier module only (with F1TE filter).

Freq (MHz)	Pin (W)	Pout (W)	Gain (dB)	IRL (dB)	Eff (%)	Vd (V)	Id (A)
50	0.2	200	30	-16	38.6	49.8	10.4
50	0.3	300	30	-16	41.7	49.8	14.6
50	0.4	400	30	-16	48.1	49.8	16.7
50	0.5	500	30	-17	53.4	49.8	18.8
50	0.6	600	30	-16	57.4	49.8	21
50	0.70	700	30	-16	61.7	49.8	22.8
50	0.88	800	29.6	-16	65.3	49.8	24.6
50 P1 dB	1	900	29.5	-16	67.9	49.8	26.6
50	1.4	1000	28.5	-16	71.7	49.8	28
50	1.8	1100	27.9	-16	74.1	49.8	29.8
50 P4dB	2.8	1200	26.3	-17	76	49.8	31.7

Table 2

This last result shows an improvement in efficiency and output power. What does that mean??

The 3rd harmonic is fully reflected back to the transistor and the amplification class is not AB any more, but closer to class F or FG. This is the reason for the 80% efficiency. But to get this result the length of the coaxial cable between the amplifier and the filter needs to be adjusted. And if the length is not correct, the results can be very bad and can even destroy the transistor. As an example, if we had 30 cm more than the existing cable the efficiency is not more than 60% and the power is limited to 900 W.

This means that for each type of filter design, the length of the cable has to be adjusted for the best efficiency. For the F1TE filter used I had to use 91 cm RG142BU cable.

Another design has to be tested for improved 3rd harmonic performance. It will be designed with a 4:1 output balun and some 2nd and 3rd harmonic traps.

5. IMD measurement

The IMD measurements were done in the same way as with the 2m amplifier. The result for Pout 800 W PEP and Idq 2 A was: IMD3 : - 28 dBc / PEP IMD5 : - 47 dBc / PEP

6. Ruggedness

The MRFE6VP61K25H is a very rugged part capable of handling 65:1 VSWR in pulse mode, it was designed for high mismatch applications, such as laser and plasma exciters, that exhibit repetitive high VSWR values at startup and then come back to a more friendly impedance. In CW, at these VSWR levels

and rated power, the limiting factor is the max. DC power dissipation. VSWR protection that shuts down the gate voltage within 10mS on a single shot will protect the transistor effectively. The amplifier presented here, was tested at all phase angles with 10mS pulses and 5% duty cycle without any faillure or degradation in RF performance.

7. Fixture layout and bill of materials

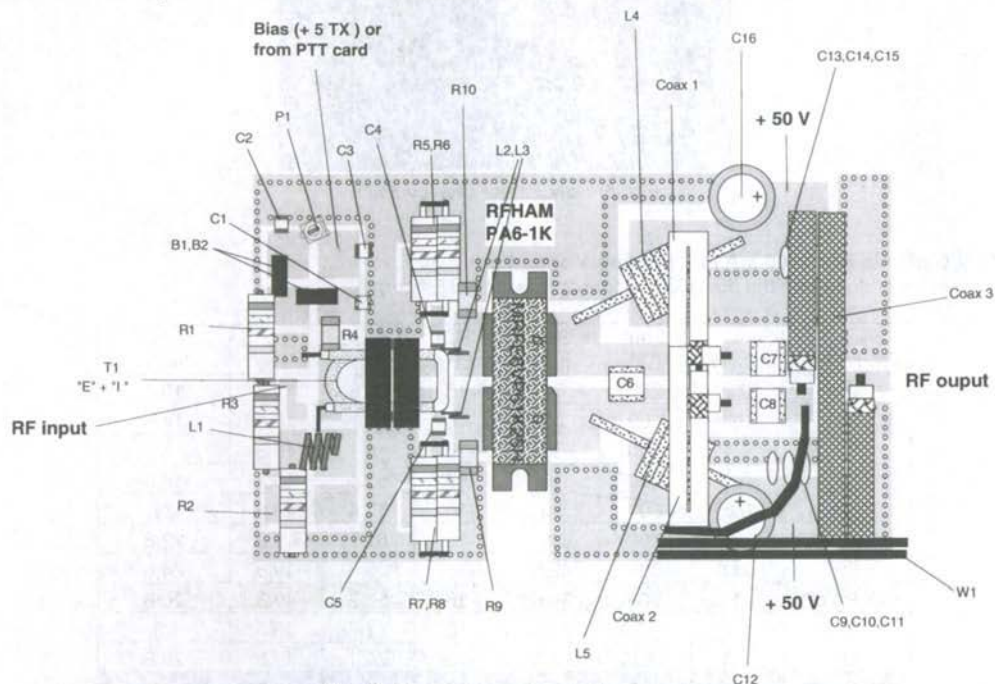


Fig. 6: Fixture layout and placement



Fig. 7: View from the side

Part	Value	No.	Brand
Teil	Wert	Best.-Nummer	Hersteller
B1,B2	Bead Long Fair-Rite (95 ohm@100MHz)	2743021447	Fair-Rite
L1 (Air inductor)	3 Turn air inductor 6 mm diameter,	Tinned copper wire of 1 mm diameter	
L2, L3 (Air inductor)	1.5 Turn air inductor 3 mm diameter	Tinned copper wire of 0.6 mm diameter	
L4, L5 (Air inductor)	7 Turn air inductor 10 mm diameter	Enamelled copper wire of 1.6 mm diameter	
C1	1 nF ATC 100B Ceramic Capacitor	ATC100B102KT500XT	ATC
C2, C3, C4, C5	100 nF Ceramic Capacitor 30 V	SMD	
C 6	75 pF CLX Ceramic Capacitor	CLX	TEMEX
C7, C8	2.7 nF CLX Ceramic Capacitor	CLX	TEMEX
C9, C10, C13, C14	1 nF Ceramic Capacitor 100 V		LCC
C11, C15	100 nF Ceramic Capacitor 100 V		LCC
C12, C16	100 uF 160V		
R1, R3	330 ohm 3 W Power Resistor	PR03	Vishay
R2	18 ohm 3 W Power Resistor	PR03	Vishay
R4	5.6 ohm 1 W Chip Resistor	2512	Vishay
R5, R6, R7, R8	33 ohm 3 W Power Resistor	PR03	Vishay
R9, R10	1 kohm 1 W Chip Resistor	2512	Vishay
P1	500 Ohms SMD pot		Bourns
T1	Balun TUI-9 Comm Concepts	TUI-9	Com Concepts or RF Power Systems
E , I	Ferrite for TUI-9 Comm Concepts	E, I	Com Concepts or RF Power Systems
Coax1, Coax2	Flex Cable (10.2 Ohm) 25cm	TC-12	Com Concepts or RF Power Systems
W1	35 cm 2 t 40 mm diameter	Enamelled copper wire of 1.6 mm diameter	
Coax3	Coax cable, 50ohm, 35 cm	RF142 BU	
PCB	Arlon TC350, 2 oz. 30 mils	PA6-1K	RFham.com

Table 3: Bill of materials

8. Construction & tuning

- 1) Put the PCB on the copper plate.
- 2) Mount SMD components and power resistors. See fig. 8.

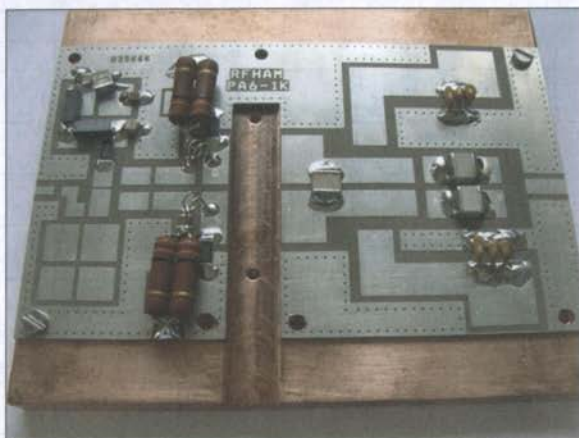


Fig. 8

3) Prepare the 9:1 input balun. See fig. 9.



Fig. 9



Fig. 10

An alternative is to use a binocular 43 mix ferrite, a description is available in (3). See fig. 10.

4) Put the balun in place. See fig. 11.

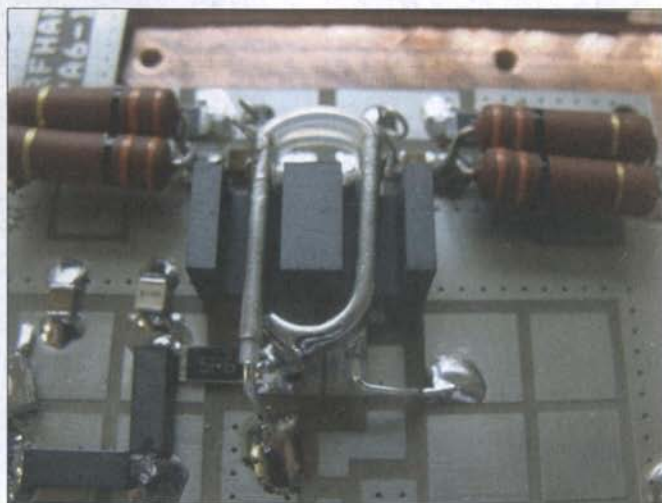


Fig. 11

5) Stick the two "I" with cyanacrylate glue and just one point of glue in the "E" and PCB.

6) prepare the 10 ohms coaxial cable, length 25 cm. See fig. 12.



Fig. 12

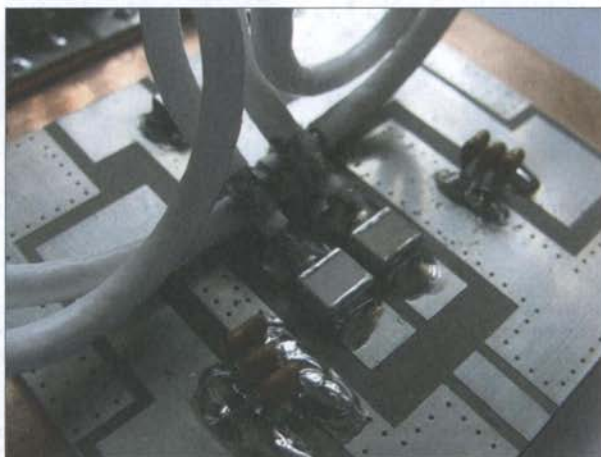


Fig. 13

7) Next step is the output balun. See fig. 14.



Fig. 14

8) Before soldering the transistor it is best to make some preliminary tests.

a) Set the pot to zero.

- b) With a DVM measure in the resistance between the gate pad and ground. It should be 5.6 ohms.
 c) If you have a "network analyzer" or any type like mini VNA you can measure the output matching of the amplifier (this method is also used for tube amplifiers). Put a 5.6 ohm resistor and a 180 pF capacitor between the two drain pads and the output match (S11) is about -20 dB (see the curve in fig. 15.)

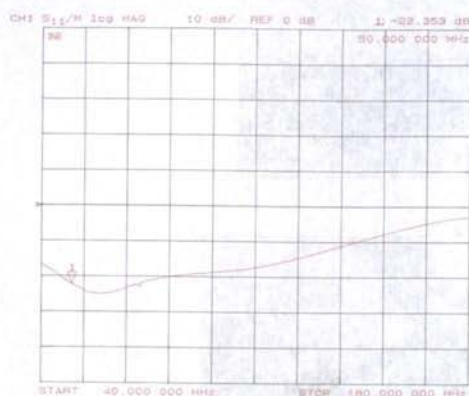


Fig. 15: Output VSWR

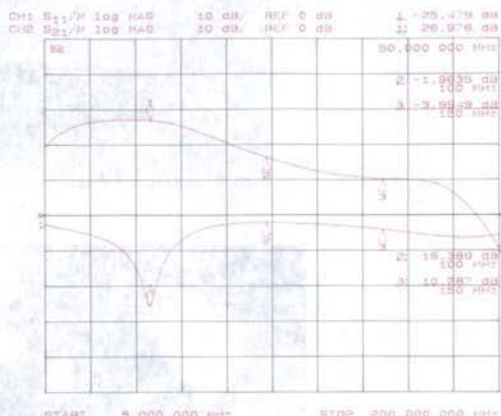


Fig. 17: Small signal gain

9) Transistor placement.

Two techniques can be used.

- The transistor can be soldered. In fact this is the better technique for having a very low thermal resistance. The disadvantage is that, if the transistor is destroyed for any reason, it will be very difficult to change it.
- Use silicon grease (the white one for a lower thermal resistance).

Before doing anything else, the transistor has to be prepared: The flange of the transistor is not very "flat". The best way to make it even is to use abrasive paper type 3 M 734 "P1200". The abrasive paper has to be put in onto a very flat surface like a piece of plate glass. Now take the transistor and move it in figure-of-8 shape with your hand until the flange is very flat. See fig. 16. Now put the transistor in place.



Fig. 16

10) Bias adjustment.

Connect the output to a 50 ohm load. Use two power supplies: One for the bias with 0 to 12 V. Set to 5 V (the pot is set to ground). Set the drain power supply to 50 V (the best is to use a 2 A max. PSU). Adjust the Idq up to 2 A.

11) Small signal test.

If you have a network analyzer or similar, test the amplifier with a small signal, otherwise with a very low output power with the appropriate load. Adjust the input VSWR by tuning L1, L2 and L3. The input return loss should be better than 15 dB. The small signal gain should be around 28 dB. If you didn't get these values, don't put the amplifier in full power mode, may be you have the output wired incorrectly.

12) High power test.

The best way to keep the transistor alive is to attenuate the input power to the amplifier. Most 50 MHz transceivers have an output power of 100 W. Although the power can be set to 10 W, if you "forget" you

will put 100 W to the input of the amplifier and destroy the transistor. In addition many amateur transceivers with power control have poor ALC and transmit a big spike at the beginning of each transmission. Several techniques can be used, like F1TE has described on his website (3). Or use a 100 W 10 dB pad and a small 3 dB resistor pad installed on the pcb.

Set the output power in the 300 W range and check the drain current: It should be about 14 A. If this is not the case, stop and check the output balun. If it is OK, you can increase the power up to 1kW.

9. Conclusion

The design has been duplicated several times and each board gave similar results, there was no need to re-tune the board to get the expected performance. But be careful, high power amplifiers can always be dangerous.

Don't forget to use protection circuits, several designs are available now (3), (4). A kit of the main components is available (5).

Many thanks to F1JRD Lionel, F4CWN Florent, Thomas Jann and F5VHX Graham.

The next article will be a 70 cm amplifier.

10. References

- (1) Lionel Mongin, F1JRD: *A compact 144 MHz High Power Solid State Amplifier using the MRFE6VP6125KH*, DUBUS 4/2010, pp 55
- (2) AN1034D Freescale (ex TRW application note)
- (3) www.f1te.org and www.f5cys.eklablog.com
- (4) www.vk4dd.com
- (5) www.rfham.com
- (6) MRFE6VP61K25 datasheet

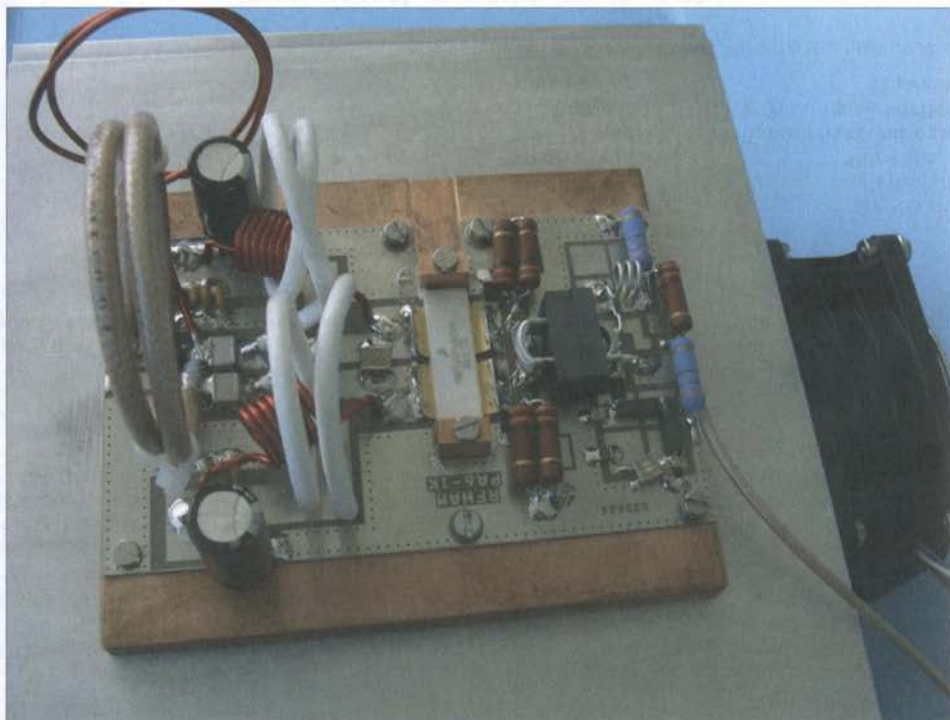


Fig. 18